2.7 In Situ Viscosity And Density Monitoring Using Quartz Resonators

Technology Need

Across the DOE complex, storage tanks containing mixed radioactive and chemical wastes must be cleaned up. This requires development of new monitoring technologies so that tank contents can be properly characterized and the mixed wastes safely transported. The TFA has identified a need for in situ viscosity and density monitors to help optimize tank sluicing operations. The monitors will measure slurry parameters both in the tank volume and in transport lines to minimize water additions needed to effectively pump the waste, and to maintain the turbulent flows needed to avoid pump or line plugging.

Technology Description

The in situ viscosity and density monitor is based on a mature liquid sensing technology that provides a precise, sensitive response proportional to the density viscosity product of a fluid contacting a quartz surface. Excitation of an acoustic wave in the thickness shear mode (TSM) in a quartz crystal viscously entrains the liquid at its surface. Changes in the fluid viscosity or density are manifested in shifts in the crystal resonant frequency and resonance damping. These parameters are measured electrically using network analysis or a specially designed "lever" oscillator circuit. Recently, this technique has been utilized in degradation monitors for jet fuels, sensors for determining the quality of cleaning baths, engine fluid condition monitors for vehicles, and cloud point determination for petroleum products.

Extending this technology to measurements in mixed waste tank slurries requires several developments: (1) determining the performance limitations in simulated wastes and understanding the quartz resonator response to solid particulates in the liquids; (2) determining the radiation and chemical resistance of the resonator, associated electronics, and required packages, and then improving their robustness; and (3) demonstrating prototype systems in the laboratory (scheduled for FY96) and the field (FY97 and FY98). Additional tasks in this project will develop and demonstrate a technique for individual determination of fluid viscosity and density, and new, remotely-operating electronic circuitry for extending resonator viscosity dynamic range, and further improving system radiation resistance. Since a single quartz resonator sensor, as used in most viscosity monitoring systems, responds only to the density-viscosity product of the contacting fluid, a dual resonator system (utilizing one smooth surface resonator and one corrugated surface resonator) will be investigated as part of task four.

Benefits

The quartz resonator viscosity and density monitor offers technical advantages not achievable by other state-of-the-art instruments: in particular real-time, in situ monitoring capabilities in a small, low-cost package. An additional advantage is the ability to implement the resonator sensors in array format, either in the same sensor head, or in separate sensor heads at multiple locations. This will enable remote, in situ monitoring at several tank and transport line locations, eliminating uncertainties in pumping operations, speeding the tank sluicing process, and lowering site cleanup costs, all while improving overall personnel safety and reducing environmental risks. Also, this viscosity and density monitor should have a range of applications that extend beyond tank slurry characterization, addressing many needs throughout the DOE community.

Collaboration / Technology Transfer

Past applications utilizing the quartz resonator fluid monitoring technology generated a high level of commercial interest. Several licenses for particular fields of use are now in place. It is anticipated that commercial interest will remain high for this technology in tank slurry viscosity and density monitoring because of the numerous benefits it offers. Selection of one or more industrial partners to participate in the final developments and demonstrations of this technology application is essential to project success.

Accomplishments

Project technical work started in November 1995. During this time, an improved version of the lever oscillator circuit that drives the quartz resonator in highly viscous fluids was characterized. The viscosity range improved to less than 1100 cP, which is more than a factor of four increase over previous versions. A matrix test approach for evaluating the response of the quartz resonators to suspended solids in simulated slurries has begun. Solids with particle sizes between 1 and 200 micrometers are mixed in concentrations of less than 60% by weight with base glycerol-water solutions. The base fluids have viscosities ranging from 1 to 60 cP. Each solution or mixture is characterized at temperatures from 20 to 80°C using a reference rotating cup viscometer and the quartz resonator monitor. Preliminary results show nonmonotonic changes in resonator response to increasing concentrations of Bentonite clay (one of the test solids) in water mixtures. Correlations of resonator response to viscosity, density, solid concentration, and shear conditions are being evaluated.

TTP Information

In Situ Viscosity And Density Monitoring Using Quartz Resonators technology development activities are funded under the following Technical Task Plan (TTP):

TTP No. AL26C213 "In Situ Viscosity And Density Monitoring Using Quartz Resonators"

Contacts

Richard W. Cernosek
Principal Investigator
Sandia National Laboratories
P.O. Box 5800, MS 1425
Albuquerque, NM 87185-1425
(505) 845-8818

Dennis Olona
Technical Program Officer
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, NM 87185-5400
(505) 845-4296

Bibliography of Key Publications

Martin, S.J., V.E. Granstaff and, G.C. Frye. "Characterization of a Quartz Crystal Microbalance with Simultaneous Mass and Liquid Loading," *Anal. Chem.* 63, pp. 2272-2281 (1991).

Martin, S.J., G.C. Frye, R.W. Cernosek, and S.D. Senturia. "Microtextured Resonators for Measuring Liquid Properties," in *Proceeds from Sensors and Actuators Workshop*, Hilton Head, SC (1994).

Wessendorf, K.O. "The Lever Oscillator for Use in High Resistance Resonator Applications," in *Proceeds from IEEE Intl. Frequency Control Symp.*, pp. 711-717 (1993).

Martin, S.J., R.W. Cernosek, and J. J. Spates. "Sensing Liquid Properties with Shear-Mode Resonator Sensors," in *Proceeds from Transducers 95/Eurosensors* IX, Stockholm, Sweden (1995).